Ecological Indicators 70 (2016) 597–605 Contents lists available at ScienceDirect Ecological Indicators journal homepage: www.elsevier.com/locate/ecolind Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management Julie Goodness a,*, Erik Anderssona, Pippin M.L. Andersonb, Thomas Elmqvist a a Stockholm Resilience Centre, Stockholm University, Kräftriket 2B, SE-10691 Stockholm, Sweden b Department of Environmental & Geographical Science, University of Cape Town, Private Bag X3, Rondebosch 7701, Cape Town, South Africa article info Article history: Received 16 September 2015 Received in revised form 22 January 2016 Accepted 5 February 2016 Available online 28 June 2016 Keywords: Social–ecological systems Biodiversity Functional traits Functional effect traits Ecosystem services Cultural ecosystem services Urban Cities Human perception Resilience Ecosystem management abstract Functional traits have been proposed as a more mechanistic way than species data alone to connect biodiversity to ecosystem processes and function in ecological research. Recently, this framework has also been broadened to include connections of traits to ecosystem services. While many links between traits and ecosystem processes/functions are easily and logically extended to regulating, supporting, and provisioning services, connections to cultural services have not yet been dealt with in depth. We argue that addressing this gap may involve a renegotiation of what have traditionally been considered traits, and a targeted effort to include and expand upon efforts to address traits-cultural ecosystem services links in traits research. Traits may also offer a better way to explore the recognition and appreciation of biodiversity. Drawing upon examples from outside the explicit traits literature, we present a number of potential connections between functional traits and cultural ecosystem services for attention in future research. Finally, we explore considerations and implications of employing a traits approach in urban areas, and examine how connections between traits and ecosystem services could be developed as indicators in a research and management context to generate a robust and resilient supply of ecosystem services. © 2016 Elsevier Ltd. All rights reserved. 1. Introduction 1.1. Functional traits and ecosystem services in urban areas Current urban planning – where it addresses biotic elements – is often geared toward protected areas and parks (rather than the full complexity of the urban matrix) and frequently concentrates on the preservation of charismatic or endangered species. While such approaches can be useful for the conservation of wellrecognized species, they do not necessarily succeed in preserving urban ecosystem function or ecosystem service provision in cities, and are unfounded in cases where species diversity does not necessarily correlate with ecosystem service delivery (Naidoo et al., 2008). It has been suggested that a functional trait approach – which describes species by characteristics that impact upon ecosystem function, and, correspondingly, can be related to ecosystem services (Díaz and Cabido, 2001) – may be a more mechanistic and useful way to interpret the complexity of the urban landscape and manage for urban ecosystem service integrity (e.g., Grime, 1997; Loreau et al., 2001; Flynn et al., 2009). It has also been proposed that a functional traits approach will form an important part of moving beyond the "low-hanging fruit" of future urban biodiversity research to provide biodiversity information of relevance to planners and decision-makers (McDonnell and Hahs, 2013). Functional traits have been discussed in terms of response traits (characteristics determining an organism's response to environmental filters or pressures) and effect traits (characteristics of an organism that impact upon ecosystem processes or services) (Díaz and Cabido, 2001; Lavorel and

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Garnier, 2002; de Bello et al., 2010). Relatively recent in the traits literature is the extension of the definition of “effect trait” to explicitly encompass not only ecosystem processes/functions, but also ecosystem services (e.g., Díaz and Cabido, 2001; Díaz et al., 2007; de Bello et al., 2010; Lavorel et al., 2011). Building on this evolving definition, in a broad review, de Bello et al. (2010) highlight 247 studies in which empirical connections can be drawn between functional traits and ecosystem services, and specifically document 548 traits-service connections (see Fig. 4 in de Bello et al. (2010) for the most commonly investigated plant and invertebrate traits and their connection to ecosystem services). Notable, however, are two distinct coverage gaps in this collection of literature, one in ecosystem itself, and one in ecosystem service category. While relationships between traits and services are recorded for a range of ecosystems, urban ecosystems are strikingly absent (de Bello et al., 2010, Fig. 1). And in terms of the ecosystem service category, cultural ecosystem services are documented much less frequently in the literature (de Bello et al., 2010, Table 1). A functional trait approach to management may prove of particular importance and utility in urban ecosystems; a lower proportion of natural elements in cities (as compared with exurban locations) implies that there are fewer areas available that can provide ecosystem services, and hence this provision must be carefully managed. Pressure is further added by the increased (and increasing) density of people that may use and depend upon services in urban areas as compared to more exurban ones. With more than 60% of the world’s population predicted to live in cities by 2030 (UN-Habitat, 2008) and approximately 60% of the globe’s entire urban extent in 2030 being built in the 30 years prior (2000–2030), we currently face the largest and fastest expansion of cities in all of human history (Elmqvist et al., 2013). Urban systems are hybrid systems of built and living environment and could be designed and managed to provide multiple ecosystem services simultaneously: for example, soil erosion control, water regulation, and aesthetic enjoyment. This kind of design and planning requires a good evidence base of how traits and services are related, as particular traits could then be selected for in order to provide desired ecosystem services and avoid disservices. In this way, traits could serve as useful indicators or proxies for potential ecosystem service provision in the landscape. A traits approach also allows for comparisons of trait-service provision across urban areas.

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1.2. Drawing connections between functional traits and cultural ecosystem services

This article aims to address the literature gaps described above through an exploratory literature examination of the relationship between cultural ecosystem services and functional traits/characteristics relevant in an urban setting. Our goal is to uncover an array of potential trait-cultural ecosystem service linkages for further examination and testing in urban research and management applications.We choose to hone in on cultural ecosystem services because we believe that the connections of traits to provisioning, regulating, and supporting services that de Bello et al. (2010) outline could already be widely applicable and relevant for urban systems. In terms of organisms, we primarily focus on functional traits of plants and birds; we elected this focus in order to provide detailed analysis on two meaningful and conspicuous taxa for humans in urban areas. Our review departs from de Bello et al. (2010) in that we cast a broader net, drawing from outside of the explicit traits literature to identify particular plant and bird characteristics that can be related to specific cultural ecosystem services. Our analysis utilizes the categories of cultural ecosystem services that have been identified for the The Economics of Ecosystems and Biodiversity (TEEB) and the

Millennium Ecosystem Assessment (MEA) (TEEB, 2010, 2016; MEA, 2003). Our overarching framework for our understanding of functional trait-ecosystem service links is depicted in Fig. 1 (adapted and modified from Lavorel and Garnier, 2002; Suding et al., 2008), in which a regional species pool is acted upon by an environmental filter of urban conditions/stressors, which filters for certain response traits and produces an urban species pool. In the urban setting, human influence plays a key role (Williams et al., 2009; Pataki et al., 2013; Hope et al., 2003; Martin et al., 2004) since humans frequently choose organisms and select for particular traits such as Fig. 1. Framework presenting the relationship between functional traits and ecosystem services in urban ecosystems. This article focuses on the boxed section of the framework in which the effect traits of an urban species set generate ecosystem services. flowering (e.g., Kendal et al., 2012) based on their needs and preferences. The resultant urban species pool then impacts upon ecosystem processes, functioning, and services through particular effect traits. These ecosystem processes, functioning, and services may then, in turn, become part of the filter that impacts upon response traits; this creates a feedback loop of effects in the system. For this article, we will focus on the boxed section of linkages between effect traits and ecosystem services in urban ecosystems (Fig. 1). Following our presentation of the literature, we synthesize key findings and gaps from the results in order to identify directions for future research. We also highlight two important additional conceptual issues to consider as we take research forward, including trait definitions and unique particularities of working with traits-ecosystem service linkages in urban environments. Finally, we consider how these trait-cultural ecosystem service connections could be incorporated into an indicators tool used for urban environmental management and planning that aims for a resilient supply of multiple ecosystem services. 2. Methods The approach to the literature review included searches run in ISI Web of Science and Google Scholar for terms used to connect specific effect traits to ecosystem processes or ecosystem services. Beyond a general query for the terms highlighted above, in another search, we focused in on particular cultural ecosystem services and generated different combinations of search terms that would draw out literature connecting specific plant and bird characteristics/qualities (i.e., traits) to cultural ecosystem services. We generated additional keywords connected to each cultural ecosystem service of interest. We used the list of ecosystem services as characterized in TEEB and the MEA (TEEB, 2010, 2016; MEA, 2003, pp. 56–60). To generate a detailed range of literature connecting plant traits and bird traits to cultural ecosystem services, topic search terms including the following were used in varying combination: • cultural ecosystem services(s); aesthetic; spiritual; recreation; cultural; health; wellbeing • plant(s); vegetation; foliage; flower(s) or bird(s) • sensation; visual; appearance; color; hue; structure; auditory; sound; song; olfactory; scent; smell; aroma; tactile; touch; gustatory; taste; edibility • preference(s); value(s); attitude(s) • human(s); people • urban; city; cities In addition to the studies found using the above approach, some were added through (1) reference lists within search-selected papers (i.e., snowballing), and (2) author prior knowledge. Specifically, we attempted to draw upon literature that made explicit J. Goodness et al. / Ecological Indicators 70 (2016) 597–605 599 treatment of the urban where possible, although we still permitted and included non-urban studies in which the broader trait-service connections may still be relevant and applied to the urban. In other words, the terms "urban," "city," and "cities" were not mandatory for inclusion in the review, but helped to highlight particularly relevant articles. Studies were only included if the results demonstrated clear links between specific organism traits/characteristics and cultural ecosystem services.We took as our chief basis functional traits that have been previously well documented in the literature (e.g., Cornelissen et al., 2003), but also considered some novel characteristics that have bearing on organism function, and also impact the benefits people obtain from ecosystems (thus fitting the definition of an effect trait). This point is further unpacked in Section 4.2.1. The resulting literature originates not just from the traits literature, but from a diversity of fields, including biology, ecology, environmental psychology, forestry, horticulture, landscape architecture and design, urban planning, and health sciences. To the authors' knowledge it is the first time that such a broad-ranging investigation of the effect traits connected to cultural ecosystem services has been made. It is important to note that this review is framed as an exploratory investigation rather than a strict quantitative analysis of all studies that describe trait-cultural ecosystem service connections. Indeed, the wide-ranging assortment of fields that were drawn upon along with the importance of snowballing precluded the establishment of strict bounds on the exact literature parameters, or the capping of the results at a set number. More studies were of relevance that can be treated here, but 89 are detailed in the body of the results. This exploratory review can serve as source material for future study and testing of trait–cultural ecosystem service connections. 3. Results The MEA defines cultural ecosystem services as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA, 2003, p. 58). In this section, we explore plant and bird traits that are linked to aesthetic, recreational, and spiritual, religious, and/or cultural benefits, particularly in the context of urban settings. We also draw connections between these traits and their influence on health and wellbeing (TEEB, 2016). All references cited in Section 3 are included in Appendix A as supplementary data. Supplementary Table 1provides a visual interpretation of the results. 3.1. Aesthetic values Aesthetics deal with evaluations of beauty and stylistic taste, in terms of entities that have sensory appeal and value. Demonstration of aesthetic value can be deduced through preferences for particular characteristics. We organize our discussion by examining traits related to the senses: visual, auditory, olfactory, tactile, and gustatory. While some traits have been well documented and established in the traits literature (e.g., Cornelissen et al., 2003), we also suggest some additional qualities that could serve as novel traits, particularly in the consideration of cultural ecosystem services. 3.1.1. Visual 3.1.1.1. Plants. Size. It has been suggested that traits of overall plant size, including and height and width, can be influential in aesthetic preference. Ulrich (1986) notes that a number of studies have suggested that large trees are preferential to small trees. In a study of urban forest scenes, Buhyoff et al. (1984) found that visual preference increases with increasing average diameter at breast height and basal area per stem. Morphology. Plant morphology can also have an impact on aesthetic preferences. Buhyoff et al. (1984) found that preference for urban forest scenes increases with greater levels of tree crown enclosure, and Lohr and Pearson-Mims (2006) discerned a preference for dense rather than open individual canopies. In studies comparing individual tree canopy shape, size, and proportions, preference was found for large-canopied, spreading-shaped trees (Lohr and Pearson-Mims, 2006; Sommer and Summit, 1995; Summit and Sommer, 1999), oval or globular shapes (Williams 2002), and a greater canopy width/tree height ratio (Heerwagen and Orians, 1993). Leaf shape can also influence aesthetic preferences; LindemannMatthies and Bose (2007) found respondents favored complex/diverse leaf forms. Williams (2002) found a preference for trees with "coarse," broad-leaved foliage over those with finely textured, needle-like foliage. Growth form. Plant growth form may also influence preferences, though there is not wide consensus on what may be universally preferred, nor if there is a preference for single growth forms. Nassauer (1993) showed respondents generally preferred lawn scenes, given a choice of growth forms ranging from solely simple grass lawns, to complex arrangements of trees, shrubs, and grasses. This may be corroborated by observations of the high prevalence of lawn landscaping style in cities (Henderson et al. 1998; Robbins and Birkenholtz 2003). However, other studies have indicated that residential scenes with prominent trees are preferred (Ulrich, 1986). For example, in one survey, people ranked views that contained trees more highly than views that were dominated by grassy areas or built features; people who had tree views in the survey also said they were more satisfied with their physical and social environment (Kaplan 1983). Aggregate vegetation structure. Beyond individual, separate characteristics of plant size, morphology, or growth form, landscape preference literature suggests that there may be particular preferences that emerge for aggregate plant structure. Vegetation scenes that display different heights and a mid-level of depth and complexity have been shown to be preferred in a number of studies (Ulrich, 1986). This mid-level complexity is also reflected in preferences particular to undergrowth forest management, in which it has been shown in Finland that forest with undergrowth is preferred over forest without (Tahvanainen et al. 2001), and low understory shrub density is preferred over non-manipulated, dense understory landscapes in the USA (Patey and Evans 1979). Alternatively, it has been shown that people tend toward appreciation of lower levels of vegetation complexity; there are indications that people prefer scenes with fewer, larger stems to those with many smaller stems in urban residential areas (Buhyoff et al. 1984). Leaf traits. Leaf traits can also influence visual aesthetic enjoyment. Leaf nitrogen and toughness (de Bello et al., 2010) as well as leaf phosphorus concentration and dry matter content (Lavorel et al., 2011) have been linked to visual preferences for litter mass accumulation and appearance. Flowering. Flowering is a conspicuous characteristic that is highly aesthetically regarded and preferred over non-flowering vegetation in a variety of settings, including highway roadside vegetation (Akbar et al. 2003), inner-city street verges (Todorova et al. 2004) and green roofs (Lee et al. 2014). On the grounds of urban businesses and offices, employees expressed greater satisfaction with opportunities for sitting outside if there were flowers located close by, and the strongest desire for changes to the grounds was to have more flowers (Kaplan 2007). Across residential landscapes in the city of Trabzon, Turkey, flowering was a salient ornamental woody plant characteristic (Acar et al. 2007), and in Faisalabad, Pakistan, urban residents preferred flowering trees (Riaz et al. 2012). In meadow assemblages that participants created at a botanic garden in Switzerland, 30% of the selected plants were flowering species (Lindemann-Matthies and Bose 2007). Size of flowers is also an influential characteristic in preference, with some general desire for large flowers (Lindemann-Matthies and Bose 2007), but possible variation among gardener "types," whose personal home styles may range from "colorful" and "lush" categories which favor larger flowers, to "modern" in which flower traits do not play as strong of a role in selection (Kendal et al., 2012). Flower height, arrangement, and variety may also be influential characteristics, with low, ordered, and single-species arrangements preferred over high, chaotic, and mixed-species arrays (Todorova et al. 2004). Phenology (timing and seasonality) traits related to blooms may also influence enjoyment (De Chazal et al., 2008). Color. Color also has an aesthetic impact, with the hue of all parts of the plant – including leaves, flowers, and fruits – influencing preferences. Colorful flowers (Lindemann-Matthies and Bose 2007) and bright flowers (Todorova et al.

2004; Berghage and Wolnick 2000) are documented as preferred, and while there is not unilateral consensus on specific color preference, a range of purple to red colors receives multiple citations as most well-liked: purple-colored flowers receive the highest ranking for city roadside verge vegetation (Todorova et al. 2004), red, lavender, and blue for general consumer evaluations of geraniums (Behe et al. 1999), and red-violet and red for impatients (Berghage andWolnick 2000). A variety of colors may also be preferred (De Chazal et al., 2008). In home gardens, preference for colorful flowers or foliage may vary along gardener's personal landscape styles (Kendal et al., 2012). In terms of plant fruit coloration, red fruits have been rated more attractive than green or brown fruits (Prokop and Fancovi ? cová ? 2012). Leaf color can also have a significant effect on garden center customers' plant preferences (Townsley-Brascamp and Marr 1994) and landscape preferences (Misgav 2000; Qin et al. 2013b). In evaluations of computer-manipulated images, trees with red or green foliage are preferred over those with purple, orange, or brown foliage (Kaufman and Lohr 2002). Green foliage is widely appreciated in many settings; it is preferred over other colors in instances of green roof vegetation (Lee et al. 2014), garden hedges (Kendal et al. 2008), and indoor plants (Qin et al., 2013a). Alternatively, for impatients, red or variegated red-green leaf color is preferred over solid green (Berghage and Wolnick 2000). In a broader landscape-perspective consideration of color as a trait (which includes possibility for variation in foliage and flower color) there is preference for a greater amount of color (Hands and Brown 2002) and a diversity of color (Fernandez-Canero et al. 2013; Hands and Brown 2002; Qin et al. 2013b; De Chazal et al., 2008) in the context of green roof, industrial/business site, and urban botanical garden settings. 3.1.1.2. Birds. Size. Small birds received the highest preference ranking in a survey of residents' attitudes toward common urban animals, which the authors suggest are perhaps due to their songs (Bjerke and Østdahl 2004). Other categories of bird, including duck, goose, and bird of prey were rated more neutrally (indicating some degree of liking). European magpie, pigeon, and seagull were rated slightly less than neutral (indicating some degree of dislike). In an evaluation of captive parrot species, however, large body size was preferred (Frynta et al. 2010). Morphology. In a survey of preference for morphology and shape of birds, Lisková and Frynta (2013) found that the shorter ? the neck and the bigger the eyes, the more attractive the species was to respondents. Frynta et al. (2010) found a preference for long tails. Color. While documented preferences for bird coloration are sparse in the literature, lightness was a preferred characteristic (Lisková and Frynta 2013). In terms of particular colors, yellow ? and blue plumage hues were most liked (Lisková and Frynta 2013, ? Frynta et al. 2010) as well as orange (Frynta et al. 2010). 3.1.2. Auditory 3.1.2.1. Plants. Screens of dense vegetation can provide noise abatement/regulation through absorbing sound, and, when integrated in the built structure, create a novel sound environment (Schafer 1977). This is also recognized as an important cultural service; for example, when asked to rate the important attributes of city trees in a survey, urban residents mentioned noise reduction as an advantageous quality (Getz et al. 1982). The sound of trees moving in the wind has also been cited as an enjoyable sound element by visitors to Israeli nature sites (Schwarz 2013) and urban streetscapes in Korea (Han et al. 2011). 3.1.2.2. Birds. Bird vocalization and birdsong are acknowledged as an important and aesthetically pleasing element in urban settings. In surveys about the composition of urban soundscapes, respondents distinguish birdsong as a prominent sound component in urban parks (Chen et al., 2009). Even if an urban landscape is dominated by anthropogenic sounds, biological sounds (biophony) can still play a significant role, with birdsong ranked as the most prominent component of biophony (Liu et al. 2013). A number of field studies have examined preference for bird sounds in urban settings. In a greenspace study, the ranking of the perceived pleasantness of three sound categories revealed a hierarchy of preference from natural, to people, to mechanical sounds. The dominant natural sound described by respondents was "birds" or "birds singing" (Irvine et al. 2009). In an evaluation of sound in an urban square, fountains and twittering of birds were most highly ranked as favorite sounds (Yang and Kang 2005). In an evaluation of different outdoor urban sounds that people could hear from their homes, bird twittering received the most positive percentage rating out of any of the sounds in the study (Tamura 2002). Experimental studies have also been used to document sound preference in urban settings. Bird song is generally rated positively (Hedblom et al., 2014), evaluated more positively than urban background sounds (Carles et al. 1992) and even other natural sounds, including water (Carles et al. 1992; Hong and Jeon 2013) or crickets (Carles et al. 1992). Even various soundscapes that include bird sound as a component (e.g., bird sounds paired with a fountain or stream) receive higher rankings compared to soundscapes without birds (e.g., a village, a quiet park, a busy park, a residential neighborhood, traffic noises, or ambient noises) (Alvarsson et al. 2010; Carles et al. 1999). Adding bird sound to a background of urban noise (e.g., traffic, construction noise, or footsteps) improves rating (De Coensel et al. 2011; Hong and Jeon 2013; Jeon et al. 2010; Viollon et al. 2002). Furthermore, adding bird sounds to urban background noise provides a greater improvement than adding other alternative sounds, such as water (De Coensel et al. 2011; Hong and Jeon 2013). A similar improvement effect is also observed in a visual case, with urban images receiving a more positive rating when combined with birdsong than when viewed alone (Hedblom et al., 2014). In a study in which respondents were asked to come up with descriptions of the sources their "ideal urban soundscape," respondents positively named birds (Guastavino 2006). Overall, while specific qualities of bird song that elicit preferences are not delineated explicitly in the literature, bird vocalization is generally documented as an item of high aesthetic worth. Hedblom et al. (2014) also found a preference for greater bird soundscape complexity, observing that singing by several species was more highly rated than singing by a single species. Some birdcalls are J. Goodness et al. / Ecological Indicators 70 (2016) 597–605 601 considered unattractive, however, such as those made by ducks, gulls, and geese (Björk 1985; Bjerke and Østdahl 2004). The nuances of these ratings merit further attention, and preferences might be linked to behavioral traits such as mating, migration, territoriality, or foraging. 3.1.3. Olfactory 3.1.3.1. Plants. Plant scent may also serve as another source of aesthetic enjoyment. Flowers and grasses, in particular, may evoke a pleasurable evaluation. For example, in an aesthetic assessment of a public garden area, a majority of respondents recognized some smells in the garden, thought it was a good smell, and identified sources of the smells as originating from flowers and grasses (Chen et al., 2009). In another evaluation of a botanic garden, areas in which flowers were present were evaluated more highly in an olfactory rating than those areas without flowers (Qin et al. 2013b). Intensity of scent also determines the level of enjoyment; in an experiment with indoor office plants in a city, employees preferred a mid-range of intensity, with lightly scented plants most highly preferred, followed by strongly scented plants, and plants without scent as least regarded (Qin et al., 2013a). While the literature does not distinguish specific nuances of scent preference, it can be said that plants with pleasant scent meet with higher preference ratings than those without. It may also be important to consider olfactory traits of plants that may provide disservices (e.g., unpleasant scents, or pollen irritants). 3.1.4. Tactile 3.1.4.1. Plants. Preferences for tactile experiences in urban settings do not receive much mention in the literature. However, in a questionnaire to visitors to a public garden, respondents reported that elements of smooth and rough tree barks, flower petals, and fine manicured turf were items that could be better appreciated if touched (Chen et al., 2009). This support for a high evaluation of plant textures is reinforced by the existence of special scent and touch gardens located in botanical gardens (e.g., Kristenbosch Botanical Garden’s Fragrance Garden) (SANBI 2014). There is also an expressed preference for avoiding plants with thorns or spines that can pose safety hazards (Larson et al. 2009). 3.1.5. Gustatory 3.1.5.1. Plants. Gustatory examinations have natural overlap with traits connected to provisioning services. However, preferences for plants that have the quality or trait of being edible may play an important role in cities. In a study of residents in the city of Mississauga, Canada, a majority of respondents indicated that they had edible food gardens in their yards (Conway and Brannen 2014). Urban residents have also named fruit-bearing as a preferred quality of trees (Pataki et al., 2013; Riaz et al. 2012). This suggests that edibility of plants may be a key consideration for selection of plants in urban settings. 3.2. Recreational 3.2.1. Plants Important plant traits pertaining to recreation often have to do with structural components, mainly height or growth form. Short height plants and growth forms (particularly grasses in the form of lawns) have been deemed as important for social interaction, relaxation and exercise (Han et al. 2013; Larson et al. 2009). Lawns are not the universal preference for recreation, however, as taller heights of plants and different growth forms have also been ranked highly. For example, urban residents have ranked grazed woodlands and open park-like landscapes good for walking (Williams, 2002). Sometimes, multiple plant heights and growth forms may be important to a recreational experience; for example, while golfers in Sweden acknowledged the importance of lawn, they also enjoyed and valued the backdrop of trees and meadow (Eriksson et al. 2015). Density and complexity also plays a role, with moderately dense scenes deemed most appropriate for recreation (Bjerke et al. 2006). Tahvanainen et al. (2001) also noted that natural-state forests (as opposed to clear cut forests) had the most positive effect on recreational value. However, it is useful to note that the specific recreational activity may have an important bearing on what qualities of vegetation are preferred; Brunson and Shelby (1992) showed acceptability of different forest management measures varied depending upon whether the setting was viewed as a place to hike or camp. Koniak et al. (2011) found that visitors preferred to hike in open garrigue (scrubland) landscapes compared to either dense scrub or pine forest, whereas for picnics, both open garrigue and planted pine forest were preferred over dense scrub. Plant age may also have an impact on recreational quality; Brunson and Shelby (1992) noted that old growth stands were ranked as more acceptable as places for hiking than for viewing scenery. Flowering traits, including density and size as well as diversity of flower type, are documented as important for recreation in the form of ecotourism (de Bello et al., 2010). 3.2.2. Birds While it has been noted generally that aesthetics and sense of fascination with birds are qualities that drive birdwatching (Kellert 1985), components that comprise this have yet to be treated in detail. Additional research may be required to isolate and identify individual bird traits most valued for recreation (e.g., color and patterning, pleasing vocalization and song, and interesting patterns of foraging, mating, or migratory behavior). 3.3. Spiritual, religious, and heritage Growth form traitsmay be tied to the spiritual component of cultural ecosystem services. Tree growth forms and forests may serve as symbolic representations of people and human qualities (Dwyer et al. 1991); they may also serve as spiritual and religious symbols across a variety of faiths and practices (Dwyer et al. 1991; Konijnendijk 2008; Sponsel 2012). Groupings of special trees, or “sacred groves” are observed around the world, for example in India (Gadgil and Vartak 1976; Gadgil, 1991), theMediterranean basin (Chandran and Hughes 2000), and Africa (Sheridan and Nyamweru 2007). Tree planting can also provide sources of emotional and spiritual recovery following traumatic events, such as wars and natural disasters (Tidball and Krasny 2013). Besides tree growth forms, plants with conspicuous flowering and fruiting traits may have spiritual connotations. Flowers have been noted as spiritual symbols and are used in a variety of religious ceremonies and practices across the world (Goody 1993). These spiritual associations have a lengthy history, with some of the earliest examples of flowers used in human burial sites stemming from 13,700 years ago (Nadel et al. 2013). While it is beyond the scope of this article to discuss in detail, there is also a large body of ethnobiology literature that outlines the connection of prominent flowers and fruits to peoples’ spiritual beliefs and practices across the globe (as well as more secular examples of general heritage or cultural importance). Examples of traits associated with general cultural identity and heritage abound not only in formal literature, but in more informal popular knowledge as well. For example, Vuorisalo et al. (2001) and Mehtälä and Vuorisalo (2010) note the cultural importance of the calls of songbirds (particularly the thrush nightingale) through the prominence of their mention in newspaper records in Finland. More informal examples of traits associated with cultural identity and heritage easily come to mind and can be elicited from popular 602 J. Goodness et al. / Ecological Indicators 70 (2016) 597–605 local knowledge (e.g., the scent, color, and flowering of lavender in France; the color, size, and taste of the smultron fruit (wild alpine strawberry) in Sweden; the morphology, color, and behavior of cranes in Japan). 3.4. Relating traits to health and wellbeing 3.4.1. Plants The general positive impact of vegetation on health and wellbeing has been broadly documented in literature. Many of these studies show positive health associations with nature vs. nonnature scenes. A classic example is Ulrich’s (1984) study that found that hospital patients who had a view out a window that looked onto a natural scene as opposed to a brick wall experienced a quicker recovery from surgery. Images containing vegetation as opposed to those without have been shown to have greater positive emotional effects (Ulrich, 1986; Ulrich 1979), as well as produce a greater relaxation response (Ulrich, 1986). Vegetation cover has also been positively associated with self-reported ratings of wellbeing (Luck et al. 2011). It has also been shown that people who live in neighborhoods with a higher density of trees on their streets report significantly better perceptions of health and significantly fewer cardio-metabolic conditions (controlling for socio-economic and demographic factors) (Kardan et al. 2015). More specifically, some particular plant traits have been shown to have a positive impact on human health and wellbeing. For example, trees with green-colored canopies, as opposed to other colors, have been shown to the most calming (Kaufman and Lohr 2004). Trees with spreading shape as compared to trees with rounded or conical forms have been associated with lower blood pressure and more positive emotional responses; similar physiological and emotional responses have been noted for dense as opposed to thin canopies (Lohr and Pearson-Mims, 2006). Greater species richness of flowering plants in yards is also associated with lower levels of allergy in residents (Hanski et al. 2012). However, it is recognized that there are few studies that focus on the very specific landscape elements that can make a difference in human health (Velarde et al. 2007; Hartig et al. 2011). Future research efforts may focus on disaggregating landscape elements into more distinct traits and evaluating them for health impacts. 3.4.2. Birds While the literature is limited, bird song has been shown to have positive impacts on wellbeing. When natural sounds of tweeting birds and a fountain were played after exposure to a psychological stressor, study participants tended to recover faster than those who were played another noise (Alvarsson et al. 2010). 4. Discussion 4.1. Key findings, gaps, and future directions for research While our study is framed as exploratory, and is not intended for detailed quantitative assessment, we can still draw some general conclusions about existing knowledge, gaps, and directions for future research (Supplementary Table 1). In terms of organisms, we noted far more literature support for plant trait-cultural ecosystem service connections than for birds. In terms of cultural ecosystem service type, we documented more information on traits connected to aesthetic benefits than recreational, spiritual/religious, heritage, health or wellbeing benefits. In terms of aesthetic benefits, we found that there was more evidence for traits connections to visual aesthetic benefits than auditory, olfactory, tactile, or gustatory. In terms of specific trait connections to cultural ecosystem services, we noted the strongest evidence (more than 5 cases cited) for the following: visual aesthetic benefits of plants were connected to large, spreading shaped individual canopies and presence of flowering. Spiritual benefits of plants were connected to tree growth form. Health benefits were connected to vegetation in general (though this has yet to be broken down more finely into specific traits). For birds, auditory aesthetic benefits were connected to presence of song. The stronger, more nuanced trait-service links that we have documented here can serve as the basis of validity testing, particularly across different geographic locations. The weaker links and gaps can provide direction for exploratory studies that further investigate which traits are connected to cultural ecosystem services, particularly underrepresented spiritual, heritage, and health benefits, as well as the non-visual sensory aspects of aesthetics (including auditory, olfactory, tactile, and gustatory elements). Investigation will also be required to identify connections between many traits that have already been well categorized in the traits literature (e.g., Cornelissen et al., 2003) and cultural ecosystem services, particularly in instances in which this relationship may be indirect (e.g., aesthetic benefits of leaf nutrient content via leaf appearance). Identification of these linkages could provide a useful bridge to the existing body of knowledge on traits. We can also further unpack the complexities of trait-service relationships. For example, in some cases, it might not be the expression of just one trait type within a trait category that is tied to a service, but the aggregate of multiple trait types within a trait category. From our results, we observed that general aesthetic appreciation of plants was often seen to emerge at increasing levels of vegetation structural complexity (Ulrich, 1986; Kaplan and Kaplan, 1989); thus the service was derived not just from one growth form trait, but from an aggregate composite of several (trees and grass), and/or several distinct levels of the trait of plant height. For future studies, a course of action is for researchers and/or managers to conduct their own assessments of the cultural ecosystem services and disservices of importance and the linked traits of importance in their study area. One promising approach is the use of ecosystem service valuation methods to determine what is most significant to stakeholders; this may include narrative methods, preference surveys, or discursive (i.e., deliberative) approaches and citizen juries (Chan et al., 2012), and can also involve mapping (Raymond et al., 2009; Sherrouse et al., 2011; Klain and Chan, 2012; Plieninger et al., 2013). While these examples explicitly address ecosystem services, it is conceivable that trait-service linkages could also be elicited using these methods. Another option is to elicit valued cultural ecosystem services from stakeholders, and then connect to traits through use of scientific expert input and existing literature (e.g., De Chazal et al., 2008). As our knowledge about the connections between traits and cultural ecosystem services develops, we can bring this into conversation with the links that have been demonstrated between traits and other ecosystem service categories, including provisioning, regulating, and supporting (e.g., de Bello et al., 2010). We can begin to explore significant relationships and identify trait-service bundles: i.e., which traits are responsible for provision of multiple services, and which suites of traits will provide key services. For example, canopy size and architecture traits previously have been linked to a number of regulating and supporting ecosystem services (de Bello et al., 2010, Fig. 4); in our review, we have also noted links of these traits to aesthetic and health and wellbeing aspects of cultural ecosystem services. From this kind of information, we can test and formulate an understanding of which assemblages of traits are vital to generate strong multifunctional ecosystem service landscapes in cities. Such information can also be used to derive scientific indicators that will show what ecosystem services are being provided depending upon the traits present in an area. Such indicators can be used in scientific assessment as well as management applications (Section 4.3). If traits are to be used to this J. Goodness et al. / Ecological Indicators 70 (2016) 597–605 603 end, we need to have a complete set of traits capable of addressing all critical ecosystem services, cultural services included. 4.2. Conceptual considerations for future work with trait-service linkages 4.2.1. What’s in a trait? A broader view of definitions The variety of potential trait-service linkages outlined in our review begs the question, what should truly be considered a “functional effect trait”? Particularly in terms of some of the characteristics we found associated with cultural ecosystem services (such as plant scent, bird song, or plant or bird color) that previously have not been integrated into the traits literature, how should these be treated? These characteristics do have bearing on organism function, and also affect the benefits people obtain from ecosystems, as many effect traits are generally currently defined (Díaz and Cabido, 2001; de Bello et al., 2010), rendering them candidates for consideration. In evaluating their merits for inclusion, it is worthwhile to reflect on our earlier observation that trait terminology and concepts are not static, and have undergone refinements over the years (Gitay and Noble, 1997; Lavorel et al., 1997; Lavorel and Garnier, 2001; Lavorel and Garnier, 2002), especially with the recent extension of the definition of “effect trait” to explicitly encompass not only ecosystem processes/functions, but also ecosystem services (e.g., Díaz et al., 2007; de Bello et al., 2010; Lavorel et al., 2011).With the addition of the language of ecosystem services, it is possible that a small vacuum has been created, and the full host of repercussions for traits lists and linkages has neither had time to manifest nor be completely realized in recent studies. This has particularly acute implications for cultural ecosystem services: mapping linkages between organism functional traits and ecosystem processes/functions has an established tradition in ecology (and is, in fact, a central research topic), and many of the connections drawn between traits and ecosystem processes/function translate logically and nicely to the new framework of regulating and supporting services; conversely, there is no such research tradition or natural translation step for drawing linkages between traits and cultural ecosystem services. This means that we must start from scratch for these trait-cultural ecosystem service linkages in the traits field (or gather evidence from other fields, as with this study). Ultimately, in order to more comprehensively and robustly connect traits to the ecosystem services concept (particularly to cultural services), we may need to expand lists of traits to accommodate additional characteristics that humans appreciate (or do not appreciate) in their landscapes. Over time, this may allow for a build-up and broader integration of trait-cultural ecosystem service linkages in the traits literature, thus addressing the distinct gap evident in de Bello et al. (2010). 4.2.2. Particularities of working in urban ecosystems: the importance of cultural ecosystem services in traits-ES evaluations and research A key feature that distinguishes urban ecosystems from nonurban ecosystems is the higher density and sheer greater number of people present. This has important implications for using a traitsecosystem services framework in urban locations: there may be a wider range and number of different trait-cultural service linkages to consider in the urban than in the non-urban, because of the diversity of people with distinct preferences and ways of appreciating the landscape. This larger array of traits-cultural ecosystem service connections will need to be integrated in indicators used for scientific assessment and management in urban areas. 4.2.2.1. Differences across cities. While there may be a wider range of trait-cultural ecosystem service linkages at play in cities than in non-urban areas, this does not mean that the array across different cities is necessarily universal; it is possible that they may differ widely or have specific nuances across cultures and geographic locations. In urban areas in India, for example, tree growth forms may be associated with spiritual services as sacred groves that are places to worship deities or ancestral spirits (Gadgil, 1991; Malhotra et al., 2001; Nagendra and Gopal, 2010). In some cases, sets of traits in the landscape may assemble into bundles to provide higher-level emergent cultural ecosystem services associated with heritage. Examples of many such varied “cultural landscapes” (Sauer, 1965; Fowler, 2003) of significance have been well-documented across the world, including Satoyama landscapes in Japan (Takeuchi et al., 2012; Kobori and Primack, 2003; Ichikawa et al., 2006; Bélair et al., 2010), rice terrace landscapes in Bali (Hakim et al., 2009), and the mosaic of fields, orchards, woodlots, and hedgerows in the Tuscany region of Italy (Farina, 2000). In these places that have been highlighted for their cultural significance, it may be an important and useful exercise to identify the key traits of importance, and examine how they come together to form these special landscapes. Such findings may be of great value in a management context, where key elements or traits can be preserved in order to maintain cultural landscapes of integrity. 4.2.2.2. Similarities across cities. This potential for difference also begs the opposite question: Are there clear trait-service patterns that emerge across multiple cities in the world? In other words, despite vast differences in culture between cities, is there some kind of general globalization and urban homogenization effect that generates common cosmopolitan suites of trait-service patterns (akin to species biological homogenization in cities as hypothesized by McKinney and Lockwood, 1999; McKinney, 2006)? And if so, when, where, and why does it occur? A baseline list of such commonalities might provide good starting points for traits-service linkages of importance to incorporate in indicators for studies and evaluations (in which stakeholder inputs are not immediately or readily available, or are difficult to gather). Patterns of global exchange of information, popular culture, and trends in landscaping styles (Ignatieva, 2011; Müller et al., 2013) may provide one source for identifying universal preferences. Landscape theory and evolutionary psychology may also serve as a baseline of prediction. One robust example is in terms of aggregated traits that comprise vegetation structure (size, shape, density, and growth/life form). The literature we reviewed points to preference for a vegetation structure of mid-level complexity (Ulrich, 1986): generally spreading-shaped trees (Sommer and Summit, 1995; Summit and Sommer, 1999; Williams 2002; Lohr and Pearson-Mims, 2006) with some kind of grassy or shrubby understory that is navigable and not too dense (Ulrich, 1986). This falls in line with the “savannah hypothesis,” which states that we are drawn to landscapes with mixed levels of grasses and spreading trees due to our early origin as a species in these types of landscapes (Orians, 1980; Wilson, 1984; Orians, 1986; Orians and Heerwagen, 1992; Heerwagen and Orians, 1993). It also corresponds with prospect-refuge theory (Appleton, 1975), and attention restoration theory, which involves recovery from attentional fatigue (Kaplan and Kaplan, 1989). Preference for moderate complexity and stimulation might also explain why we prefer intermediate levels of smell (Qin et al., 2013a), complex bird soundscapes with multiple species singing (Hedblom et al., 2014), and varied plant textures (Chen et al., 2009). Ultimately, comparisons across future studies conducted in different locations, or studies that explicitly make comparisons of trait-service connections across locations or cultures will further reveal whether there are universal preferences and possible explanations for universality. In our review, comparisons of particular trait-service connections across cultures are not explicitly made. 604 J. Goodness et al. / Ecological Indicators 70 (2016) 597–605 While there are not enough individual cases in our data to make proper comparisons across locations, the bulk of our studies are drawn from Europe and North America, so additional data will be required from other areas. 4.3. Future directions for ecosystem management Bringing a traits approach from study into management applications will involve careful identification of ecosystem service provision goals, and targeted use of knowledge on trait-service connections gained through research. Ecosystem service goals can be informed through existing city target plans, and/or social science survey methods in which area stakeholders and citizens, as well as local experts, identify traits and services of high importance (Section 4.1). Locally tailored trait-service indicators can be used to evaluate current supply of ecosystem services, and plan design interventions to meet goals and demand. It is possible that certain services be augmented, reduced, eliminated, or even new services added by changing trait composition and spatial arrangement. This also involves careful consideration between possible synergies and tradeoffs, for traits and linked services. Ultimately, across all management situations, there will be an aim to achieve a robust multi-functional landscape goal, in other words, to realize a high degree of targeted services across service types. Deliberate consideration of design for multi-functionality is crucial within the frame of the urban areas, for while managers can plan for key regulating, supporting, and provisioning services through the selection of traits, they also have the opportunity to make these landscapes culturally satisfying for large numbers of urban residents. Policy-makers, landscape architects, and city planners are key management actors for influencing traits and connected ecosystem services in urban areas. Policy-makers may structure ordinances and by-laws that help to influence, promote, and protect the presence of certain traits and connected services. Landscape architects and city planners can integrate provisions for specific traits and services into their designs and plans. In this way, managers can contribute toward shaping landscapes of both social and ecological integrity. Monitoring and evaluation will make management an iterative process, linking from management actions, back to stages of social and ecological evaluation. In this manner, it can be assessed how well previous trait-service goals have been achieved, as well as the need for changes in the goals themselves. Such reflections may be useful in efforts to achieve a robust and resilient supply of ecosystem services in the face of change over time. 5. Conclusion While research on functional traits and their connections to ecosystem processes and services is an ongoing and emerging field (particularly for cultural ecosystem services and in urban systems), there is promise in connecting these concepts to urban planning and management. Currently, in terms of using species as chief criteria for management, we are employing a partially blind view of the landscape. Species data alone does not provide clear links to ecosystem processes or ecosystem functions and services. And it is arguably in cities, where concentrations of people, competition for land, and demand for ecosystem services are highest, that understanding the foundation of ecosystem services is most needed. A functional trait approach might serve as one possible tool to bridge this gap, especially if we better understand how bundles of traits are connected to ecosystem services. Exploring the opportunity for ways to assess arrays of traits and services may help managers to develop tailored indicators for service provision, conduct land use assessments, generate plans for future provision of services, and even manage for future risks, uncertainties, and tradeoffs and synergies. Furthermore, locally focused qualitative assessments may help to increase understanding of residents' preferences and values related to specific services and linked traits. This renders possible design of urban systems for multiple service types, including regulating, supporting, and provisioning as well as cultural. A combined social-ecological perspective is required to determine which traits and services matter, and how to manage accordingly. Ultimately, a better understanding of the relationship between effect traits and ecosystem services may help to further envision feedback to response traits and may aid in assessing the resilience of different services to various filters, ranging from localized urban pressures to more large-scale global environmental change (Fig. 1). There is great opportunity to use a functional trait approach as a lens to more fully understand the full detail, richness, and complexity of urban ecosystems, in order to provide for better human use and wellbeing. Acknowledgements This research was supported by Mistra through a core grant to the Stockholm Resilience Centre at Stockholm University. Comments from two anonymous reviewers helped to improve the manuscript. Appendix A. Supplementary data The references cited in Section 3, Results, are included as supplementary data in two forms: (1) a list, and (2) a table sorted by cultural ecosystem service, trait category, and specific trait. Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2016. 02.031.